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Radiation Sources in Secondary Schools

Report of a Limited Survey

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Public Health Service
Consumer Protection and Environmental Health Service
Environmental Control Administration
Bureau of Radiological Health
Rockville, Maryland, 20852

Foreword

The Radiation Control for Health and Safety Act, Public Law 90-602, which was enacted in October 1968, calls for the establishment of an electronic product radiation control program to protect the public health and safety from electronic product radiation. Section 356 of the Act directs, among other activities, that there shall be study and evaluation of emissions of, and conditions of exposure to, electronic product radiation and intense magnetic fields.

In carrying out its responsibilities under Section 356 of the Act, the Bureau of Radiological Health conducted a joint State-Federal survey in a nationwide selection of schools to assess the type, quantity, and use of potential or actual radiation emitting sources in science classrooms. The survey was initiated in response to reports received from State and local radiological health agencies indicating radiation producing devices were being used in secondary school classrooms in a manner contrary to recognized safe radiological health practices.

This report is the result of the cooperation and support of many individuals and organizations. I would like to express my appreciation to the State and local school authorities for their participation and to the individual science instructors for their cooperation during the period of the surveys. In particular, I wish to acknowledge the contribution of the following State and local radiological health programs:

California State Department of Health
Colorado State Department of Health
Florida State Board of Health
Georgia Department of Public Health
Illinois Department of Public Health
Maryland State Department of Health
Massachusetts Department of Public Health
Missouri Department of Public Health and Welfare
North Carolina State Board of Health
Pennsylvania Department of Health
Philadelphia Department of Public Health
Texas State Department of Health

Personnel of the Office of Regional Operations, Divisions of Medical Radiation Exposure and Electronic Products, and the Population Exposure Studies Branch, Bureau of Radiological Health, participated in the study design, orientation sessions, and data evaluation of this survey.

John C. Villforth
Director
Bureau of Radiological Health

Contents

	Page
Foreword	iii
Part I: INTRODUCTION	1
Part II: METHOD AND PROCEDURE	3
Part III: SURVEY FINDINGS	4
Part IV: RECOMMENDATIONS	7
References	9
Annex A: Geographic Locations of Department of Health, Education, and Welfare Regions	35
Annex B: High School Radiation Survey Questionnaire	39
Annex C: Recommended Radiation Survey Procedures and Spark Gap Conversion Table	49

Tables

		Page
1.	Enrollment in Secondary Schools	13
2.	Number of X-ray Tubes in Secondary Schools	14
3.	Measured Exposure Rates from Unshielded X-ray Tubes in Secondary Schools	15
4.	Use of X-ray Tubes in Secondary Schools	16
5.	Number and Type of Gaseous Discharge Tubes in Secondary Schools	17
6.	Measured Exposure Rates from Gaseous Discharge Tubes Used to Demonstrate Heating Effects in Secondary Schools	18
7.	Measured Exposure Rates from Gaseous Discharge Tubes Used to Demonstrate Magnetic or Deflection Effects in Secondary Schools	19
8.	Measured Exposure Rates from Gaseous Discharge Tubes Used to Demonstrate Shadow or Fluorescence Effects in Secondary Schools	22
9.	Measured Exposure Rates from Miscellaneous Gaseous Discharge Tubes in Secondary Schools	24
10.	Number and Type of High Voltage Generators in Secondary Schools	26
11.	Number and Type of Radioisotopes in Secondary Schools	27
12.	Number of Radioisotopes in Secondary Schools	29
12a.	Number of Radioisotope Kits in Secondary Schools with Unspecified Contents	29
13.	Storage of Radioactive Materials in Secondary Schools	30
14.	Number and Type of Non-Ionizing Radiation Sources in Secondary Schools	31
15.	Use of Non-Ionizing Radiation Sources in Secondary Schools	32

Page

16. Type of Ionizing Radiation Detection Instrumentation in Secondary Schools 33

17. Availability of NCRP Report No. 32, "Radiation Protection in Educational Institutions" in Secondary Schools 34

Part I
INTRODUCTION

The Bureau of Radiological Health has received reports from State and local radiological health agencies indicating that radiation producing sources were being used in secondary school classrooms for teaching purposes in a manner contrary to recognized safe radiological health practices.

With respect to the uses of ionizing radiation in educational institutions, the following Maximum Permissible Doses are recommended in NCRP Report No. 32 (1):

"1. Persons in the general population at any age. Such individuals should not receive an exposure exceeding 0.5 rem per year in addition to natural background and medical exposures. (This limit applies to those persons who are not occupationally exposed. If a teacher or student of age 18 or greater is subjected routinely to work involving radiation, as discussed in NCRP Report No. 17, then he is an occupational worker and the exposure limits defined therein apply.) Medical and dental exposures are to be made at the discretion of the doctor and dentist, and are not to be considered in the evaluation of the individual's whole body exposure.

2. Persons under 18 years of age. These young people shall not be occupationally exposed to radiation. (They should not be employed or trained in an x-ray department, radioisotope laboratory, or industrial radiation facility.)

3. Students under 18 years of age exposed during educational activities. Such individuals should not receive whole body exposure exceeding 0.1 rem per year due to their educational activity. To provide an additional factor of safety, it is recommended that each experiment be so planned that no individual receives more than 0.01 rem while carrying it out.

4. Students over 18 years of age exposed during educational activities fall into Category 1 above."

The primary goal is to minimize radiation exposures and eliminate all unnecessary radiation exposures to the individual as well as the general population.

In order to define more clearly the nature and extent of the problem involved in the use of radiation producing sources in the secondary school classroom, a limited survey was conducted in April 1969. The survey involved 181 schools in Boston, Chicago, Dallas-Fort Worth,

Denver, Kansas City, Philadelphia, San Francisco, and selected areas in North Carolina and Florida.

The specific objectives of the survey were to:

A. Identify the types and number of sources which actually or potentially emitted radiation.

B. Determine whether communications between school administrations and radiological health agencies effectively promoted radiation protection.

C. Develop recommendations to promote sound radiological health practices in educational institutions.

D. Estimate the number of students who used or could be exposed to radiation producing sources.

In reference to the last objective, no suitable method of accurately determining the population exposed to radiation producing sources could be made by the survey. The only measure of the student population which could be exposed was those students enrolled in science courses (e.g., chemistry, physics, biology) (Table 1). However, there were too many variables in using this criterion to draw any valid conclusions as to the number of students who might be exposed to radiation producing sources in the classroom.

In September 1968, prior to conducting this survey, the Bureau of Radiological Health sent a letter to scientific supply companies requesting information on their sales practices when distributing X-ray producing equipment to educational institutions (2). Because of the limited response to this inquiry and the preliminary results from a Bureau of Radiological Health laboratory evaluation of examples of the type of X-ray and gaseous discharge tubes used in schools (3), the Bureau sent a follow-up letter in May 1969 to scientific supply companies requesting more specific information on their sales practices involving educational institutions (4).

The distributors indicated that they did not supply any radiation protection literature to the purchaser regarding demonstration-type gaseous discharge tubes. Some distributors did provide information regarding the use of cold cathode tubes. Few distributors advise purchasers that registration of the devices may be required by the State radiological health agencies (5).

In addition to the above actions, an identical memorandum was sent by the Bureau of Radiological Health to its regional representatives in May 1969, outlining interim recommendations regarding the use of radiation producing sources in high schools (6). It was requested that this information be transmitted to State radiological health agencies for their use.

Part II
METHOD AND PROCEDURE

The survey was conducted in the nine Department of Health, Education, and Welfare regions (Annex A). The survey employed nine teams of radiological health specialists consisting of one person from the Bureau and one person from the respective State radiological health program. In one region it was necessary to use two Bureau team members because of the unavailability of a State representative.

Prior to conducting the survey, the teams were assembled for a two-day administrative and technical orientation and training seminar at the Bureau of Radiological Health headquarters in Rockville, Maryland. The teams were familiarized with the survey questionnaire and survey procedure (Annex B and C).

Although the survey sample was selected to provide some degree of geographic distribution, it was not intended to be statistically representative of United States secondary schools. Nearly all schools were located in or near metropolitan areas for the convenience of conducting the survey. Therefore, the data in this report cannot be extended to produce a statistically valid estimate of the number and nature of the use of radiation producing sources in United States secondary schools.

Only those sources used in the teaching process were included in the survey. Radiation producing equipment used in maintaining the building or in other service areas was not included.

Part III
SURVEY FINDINGS

As a result of this survey, two major conclusions were reached:

> It was evident that a significant number of radiation sources were available which, when used improperly, could pose a potential exposure problem to teachers and students.
>
> It was found that secondary school teachers were largely unaware of the contents and availability of NCRP Report No. 32 on the safe use of radiation sources for teaching purposes.

Significantly large numbers of both ionizing and non-ionizing radiation sources are available in the school classroom. Examples of ionizing sources included X-ray and gaseous discharge tubes and radioactive materials. Non-ionizing sources included laser and microwave devices and ultraviolet lights.

Radiation emission measurements were made in the classrooms on selected ionizing sources. Measurements were not taken for each tube because of time limitation of the survey teams and school personnel. In some cases, a suitable power supply was not available to activate the tubes. The instrument used in this survey was the Nucor CS-40A with a specially-designed radio frequency interference shield. For detailed information on the laboratory findings and instrumentation, see the technical report entitled "X-ray Emissions from Cold Cathode Gas Discharge Tubes used for Educational Purposes" (3).

No measurements were taken of non-ionizing radiation sources because of the unavailability of a suitable field survey instrument.

In the 181 schools surveyed, 103 X-ray tubes were found (Table 2). Of these, 97 were unshielded tubes. An additional six tubes were components of functional radiographic and fluoroscopic units. The unshielded cold cathode and Coolidge X-ray tubes emitted the highest levels of radiation of all the sources measured.

Measurements were made of 21 of the 97 unshielded X-ray tubes (Table 3). The measured exposure rates ranged from 0 to a calculated high of 108,000 mR per hour at 24 inches from the midpoint of the tube.

It should be understood that many of the X-ray tubes were reported as not used (Table 4). Nonetheless, these tubes were available and, if used in the classroom, could be a potential problem from the viewpoint of radiation exposure.

Another source of X-ray production was the gaseous discharge tubes used to demonstrate physical phenomena such as heating, deflection, fluorescence, kinetic energy, and other electromagnetic characteristics. While the

basic purpose of the tubes is to produce the indicated effects, X-rays can be produced in the process of operating them at voltages higher than required for these effects. A total of 414 gaseous discharge tubes was found in the schools (Table 5).

The exposure rates from these tubes varied considerably depending on the vacuum present in the tubes, the voltage applied, anode or target material, and shielding provided by the tube itself.

Typical measured exposure rates from the heating effects tubes varied from 0 to 4,000 mR per hour at 12 inches (Table 6).

The most frequently used gaseous discharge tube was the deflection or magnetic effects tube (Table 7). Again, the exposure rate varied widely, ranging between 0 and 1,500 mR per hour at six inches from the midpoint of the tube.

Another commonly used tube was the shadow or fluorescence effect tube (Table 8). The measured exposure rates from those tubes varied between 0 and greater than 5,000 mR per hour at 12 inches.

Other less frequently used tubes, such as the kinetic energy, canal ray, vacuum discharge, cathode ray display, and Geissler tubes, were found to produce little or no X-radiation (Table 9). The available power supplies used primarily in conjunction with gaseous discharge tubes are indicated in Table 10.

A total of 628 identifiable radioisotopes was found. Most of the sources were in the "generally licensed" category. The most significant findings consisted of the 281 unspecified sources and 132 kits with unidentified contents (Table 11). The unidentified sources might not be a problem, but as the sources were not labeled, the possibility and severity of radiation exposure problems were not determined.

In a few cases, licensable quantities of radioactive materials were found. For example, this included one 20-microcurie source of radium-226 (licensed by the State radiological health agency), two 7-microcurie sources of radium-226, one 50-microcurie source of phosphorus-32, and one 10-microcurie source of cobalt-60 (not licensed). The distribution of radioisotopic sources and radioisotope kits with unspecified contents varied per school (Table 12). Approximately 72 percent of the schools had radioisotopic sources and approximately 18 percent had radioisotope kits.

Radioactive sources were stored within classrooms in desks, cabinets, and storerooms in such containers as lead, plastic, and metal boxes. Eighty-six schools had their storage areas clearly marked as containing radioactive sources (Table 13).

An assortment of non-ionizing radiation sources was found, as shown in Table 14. The most frequent source was ultraviolet lights. However, the

most significant non-ionizing sources were the 15 laser devices. In addition, several teachers indicated that they had ordered lasers, or that students intended to construct them in the near future. It is believed that the 15 lasers found in the schools produced low power density levels; however, this could not be confirmed because the survey teams did not have the instrumentation to measure their output.

Another commonly found source was the small microwave generator. Although it is believed these generators were low power level models and unlikely to pose a hazard, this could not be measured because suitable survey instrumentation was not available.

Thirty-eight percent of the non-ionizing sources were used by the instructor during classroom demonstrations (Table 15). It was reported, however, that one laser was used by a student. Several of the microwave generators were also used by students.

Over 700 assorted instruments, plus 25 civil defense kits, used for detecting ionizing radiation were found in the 181 schools (Table 16). The most popular was the Geiger-Mueller tube. No effort was made during the survey to check calibration of the instruments. It was noted that some of the instruments were inoperative.

Of particular importance was the fact that radiation detection equipment available in the schools was useful only for ionizing radiation. Since non-ionizing sources, particularly microwave and laser devices, are used, suitable instrumentation for measuring their energy output needs to be developed at a reasonable cost for utilization in educational institutions.

One of the most significant findings of this survey was the totally inadequate supply of radiation protection literature available in secondary schools. This point is illustrated in Table 17. In the 181 schools surveyed, only 16 teachers indicated they had read radiation protection literature such as NCRP Report No. 32. This number would have been substantially lower except that this report had been distributed by a local radiological health agency to schools in one metropolitan area in Region II prior to the survey. The lack of radiation protection literature poses a serious problem and needs immediate attention. This reflects improved communication needs to be established between the school administrations and radiological health agencies.

Part IV
RECOMMENDATIONS

As a result of this survey, it is recommended that Federal and State radiological health programs take the actions listed below.

A. The Department of Health, Education, and Welfare should:

1. Establish performance standards for radiation producing equipment and for equipment emitting radiation incidental to its intended use. These standards should include a requirement that appropriate voltage settings and other operating directions be permanently affixed to the tubes. Vacuum tubes should be of appropriately shielded design so as to comply with radiation emission standards even when operated at the highest expected power.

2. Require that all X-radiation producing tubes and devices be clearly labeled by the manufacturer as X-ray producers when energized, and require manufacturers, vendors, and suppliers to include safety literature with the equipment they sell.

3. Require suppliers of radiation producing equipment to inform purchasers of applicable State and Federal regulations regarding the possession and/or use of such equipment.

4. Establish a brief training course for teachers in the safe use of radiation producing sources in educational institutions. This should include interpretations and applications of NCRP Report No. 32 and other pertinent literature. Consideration should be given to the production of appropriate training materials for use in schools, such as: motion picture films, audiotape and/or videotape recordings, other visual aids, lecture demonstration arrangements, etc.

5. Encourage writers and publishers to include safety information in texts, laboratory manuals, and other instructional literature.

6. Conduct laboratory testing of selected equipment on a continuing basis to assess potential radiation hazards.

B. State radiological health agencies should:

1. Communicate with State educational agencies to insure that all teaching personnel responsible for the use of radiation producing equipment are familiar with pertinent existing State regulations, NCRP Report No. 32, and other recognized guidelines. Sufficient numbers of copies of suitable guidelines should be made available by health or educational agencies to all schools using radiation producing sources.

2. Consider the feasibility of registering the schools using nonexempt radiation sources and perhaps selected radiation producing sources used in the classroom.

3. Examine existing licensure and registration practices to determine if they meet educational requirements or whether special regulations may be needed.

4. Advise equipment manufacturers and distributors of State requirements regarding the sale of radiation producing sources to educational institutions. The States without this specific regulatory authority should consider establishment of such requirements and advise when they are established.

5. Cooperate with the educational agencies and conduct a continuing inspection and surveillance program of radiation equipment and radioactive materials to insure against possible radiation hazards in schools.

In light of the above recommendations, the following suggestions are made for school authorities and for manufacturers and suppliers of radiation equipment used in schools.

C. The school agencies should:

1. Establish, in cooperation with the appropriate State or local radiological health program, a system for the identification and registration of radiation facilities and selected radiation producing sources.

2. Seek the advice and consultation of the State radiological health agency on matters relating to radiation protection.

D. The manufacturers should:

1. Explore alternative means to attenuate the emission of X-rays by gaseous discharge tubes.

2. Develop appropriate literature about the safe operation of such equipment for distribution to purchasers.

3. Apply a nonremovable warning label clearly to all X-ray producing tube housings and controls. For gaseous discharge tubes producing radiation incidental to their intended use, the nonremovable warning label should be applied to the bare tube.

4. Inform purchasers about applicable State and Federal regulations pertaining to the possession and/or use of such equipment.

References

1. National Council on Radiation Protection and Measurements. Radiation Protection in Educational Institutions, NCRP Report No. 32. NCRP Publications, Washington, D.C. 20008 (July 1, 1966).

2. National Center for Radiological Health Weekly Bulletin, Vol. II, No. 36. Identical letter from Chief, Radioactive Materials Section, MORP, BRH, to eight scientific equipment suppliers, September 17, 1968.

3. Properzio, William S., Woodcock, Ray C., and Heidersdorf, Sidney D. X-ray Emission from Cold Cathode Gas Discharge Tubes used for Educational Purposes, September 1969 (in preparation).

4. Bureau of Radiological Health Weekly Bulletin, Vol. III, No. 20, May 19, 1969. Identical letter from Director, DMRE, BRH, to distributors of scientific supplies, May 9, 1969.

5. Gundaker, Walter E. Status Report: Inquiry to Distributors of Scientific Supplies, August 29, 1969 (unpublished report).

6. United States Department of Health, Education, and Welfare, Public Health Service, Bureau of Radiological Health. Memorandum of May 9, 1969, outlining interim recommendations regarding the use of radiation producing sources in high schools.

TABLES

Table 1. - Enrollment in Secondary Schools
(181 Schools)

Region*	Number of Schools	Approximate Enrollment	Estimated Enrollment in all Science Classes
Total	181	330,236	156,194
I	20	27,644	18,583
II	20	49,809	33,936
III	19	21,170	3,861
IV	20	47,849	27,516
V	20	50,257	8,838
VI	20	31,414	14,791
VII	21	34,950	14,150
VIII	21	33,405	15,653
IX	20	33,738	18,866

*Refer to Annex A for geographic location of specific regions of the U. S. Department of Health, Education, and Welfare.

April 1969

Table 2. - Number of X-ray Tubes in Secondary Schools
(181 Schools)

Region	Number of Schools	Number of Tubes	Unshielded X-ray Tubes		Radiographic Units	Fluoroscopic Units
			Cold Cathode	Coolidge		
Total	181	103	80*	17	5	1
I	20	12	7*	4	1	0
II	20	12	11	1	0	0
III	19	4	1	1	2	0
IV	20	8	6	2	0	0
V	20	17	16	0	1	0
VI	20	14	8	6	0	0
VII	21	6	5	0	1	0
VIII	21	13	12	1	0	0
IX	20	17	14	2	0	1

*Includes one unspecified type of X-ray tube.

April 1969

Table 3. - Measured Exposure Rates from Unshielded X-ray Tubes in Secondary Schools

School Identification Number	Spark Gap Measurements (Centimeters)	Measured Exposure Rate mR/hour at:		
		6"	12"	24"
105	5.1	-	-	10,000(B)
211	Undetermined	0	0	0
213	1.3	30,000(B)	7,000(B)	2,000(B)
216	7.5	36,000(B)	9,000(B)	2,000(B)
219	3.5	600(NI)	300(NI)	30(NI)
220	6.5	>50,000(B)	30,000(B)	6,000(B)
407	7.0	-	-	5,000(B)
409	0.6	-	-	10(A)
415	3.8	-	<10(NI)	-
415	3.8	-	-	5,000(C)
418	9.0	-	-	500(A)
517	2.5	-	-	16,000(A)
519	Undetermined	-	-	2,700(C)
603	0.5	0	-	-
603	0.5	0	-	-
710	1.3	0	-	-
719	1.9	-	-	40,000(C)
720	8.9	-	-	45,000(C)
902	8.5	-	-	500(A,B,C)
912	3.0	-	500(NI)	-
915	8.5	-	-	108,000(A)*

- Indicates no measurement taken.
A,B,C Indicates the location of the specific radial (direction) from the X-ray tube at which radiation readings were measured. Refer to Annex C, Figure 1, page 56.
NI Not indicated.
* Calculated from 40,000 mR/hour at 1 meter.

Table 4. - Use of X-ray Tubes in Secondary Schools
(181 Schools)

Source	Number of Sources	Method of Use			Not Used	Use Not Stated
		Demonstration by Instructor	Laboratory Use by Student	Used by Instructors & Students		
Total	103	15	1	1	83	3
Cold Cathode	80*	13	1	1	64*	1
Coolidge	17	0	0	0	17	0
Radiographic	5	2	0	0	2	1
Fluoroscopic	1	0	0	0	0	1
Hand Held Fluoroscopic Screens	18	0	0	1	16	1

*Includes one unspecified type of X-ray tube.

April 1969

Table 5. - Number and Type of Gaseous Discharge Tubes in Secondary Schools
(181 Schools)

Region	Number of Schools	Number of Tubes	Type					
			Heating Effects	Magnetic or Deflection Effects	Shadow or Fluorescent Effects	Kinetic Energy Effects	Canal Ray	Vacuum Effects
Total	181	414	33	149	119	28	25	60
I	20	41	4	16	10	2	5	4
II	20	58	9	17	17	2	4	9
III	19	42	3	22	10	0	4	3
IV	20	29	1	7	11	0	2	8
V	20	64	3	21	17	4	7	12
VI	20	32	2	12	7	1	0	10
VII	21	24	3	9	7	3	0	2
VIII	21	64	4	23	21	8	2	6
IX	20	60	4	22	19	8	1	6

Table 6. - Measured Exposure Rates from Gaseous Discharge Tubes Used to Demonstrate Heating Effects in Secondary Schools

School Identification Number	Spark Gap Measurements (Centimeters)	Measured Exposure Rate mR/hour at:		
		6"	12"	24"
107	12.7	-	0	-
107	12.7	-	0	-
114	1.9	-	0	-
116	3.2	-	4,000	-
213	1.3	100	22	5
312	1.9	350	100	50
513	Undetermined	-	-	180
518	10.2	-	-	0
605	8.9	0	-	-
612	3.2	0.5	-	-
720	8.9	0	-	-
814	Undetermined	2	-	-
814	Undetermined	5	-	-
817	8.5	0	0	0

- Indicates no measurement taken.

April 1969

Table 7. - Measured Exposure Rates from Gaseous Discharge Tubes Used to Demonstrate Magnetic or Deflection Effects in Secondary Schools

School Identification Number	Spark Gap Measurements (Centimeters)	Measured Exposure Rate mR/hour at:		
		6"	12"	24"
101	1.9	3	-	-
102	2.5	250	85	-
105	5.1	-	40	-
106	4.8	-	350	-
107	12.7	-	50	-
108	Undetermined	0	-	-
110	1.5	-	0	-
112	2.9	-	0	-
113	5.0	-	150	-
114	4.0	-	140	-
114	1.9	-	0	-
114	1.9	-	90	-
115	2.2	-	0	-
203	1.5	50	35	9
203	1.5	50	20	4
205	1.5	0	0	0
208	1.5	0	0	0
209	7.5	-	225	150
209	7.5	450	125	35
212	1.5	40	6	1
213	1.3	100	50	25
215	1.5	0.9	0	0
216	7.5	45	20	8
219	3.5	150	60	18
220	6.5	5	4	0.5
308	3.2	100	50	12
311	2.2	350	110	40
311	2.2	400	100	37
311	2.2	100	45	8
311	2.2	100	50	20
311	2.2	120	60	20
311	2.2	80	45	10
311	2.2	400	100	30

Table 7. - (Continued)

School Identification Number	Spark Gap Measurements (Centimeters)	Measured Exposure Rate mR/hour at:		
		6"	12"	24"
312	1.9	300	100	50
316	Undetermined	160	80	40
317	5.1	600	320	120
317	2.6	0	0	0
319	1.0	0	0	0
319	1.0	0	0	0
319	1.0	0	0	0
407	2.8	-	-	50
413	Undetermined	-	-	0
414	3.2	-	-	60
415	3.8	-	-	<10
418	9.0	-	-	30
501	2.5	-	40	-
504	2.5	-	-	50
507	Undetermined	-	-	0
508	2.0	-	-	10
509	Undetermined	-	-	0
509	Undetermined	-	-	0
510	3.8	-	0	0
511	2.5	-	-	800
515	Undetermined	-	0	0
517	2.0	-	-	10
518	Undetermined	-	-	300
518	Undetermined	-	-	300
519	Undetermined	-	-	3
520	Undetermined	-	-	200
603	0.5	0	0	0
605	8.8	0	-	-
607	2.8	1.5	-	-
611	2.5	15	5	-
612	3.2	180	15	10
613	Undetermined	500	100	42.5
614	2.5	220	25	5
617	1.3	-	50	17*
709	Undetermined	4.5	-	-

Table 7. - (Continued)

School Identification Number	Spark Gap Measurements (Centimeters)	Measured Exposure Rate mR/hour at:		
		6"	12"	24"
712	2.1	0	-	-
713	3.8	24	-	-
719	1.7	1.5	-	-
720	3.5	1,500	-	-
804	Undetermined	0	0	0
809	1.3	-	-	3.5
811	Undetermined	0	0	0
814	0.4	10	-	-
814	0.4	0	0	0
814	0.4	0	0	0
814	0.4	0	0	0
814	0.4	0	0	0
816	2.7	-	-	25
817	8.5	-	-	150
901	1.0	0	-	-
902	2.7	-	-	150
903	2.5	-	-	100
904	6.5	200	-	-
904	2.5	-	-	200
905	2.0	-	-	3
910	Undetermined	0	-	-
911	1.7	10	-	-
912	1.0	<1	-	-
913	1.0	5	-	-
917	1.7	-	5	-
918	Undetermined	-	-	30
918	Undetermined	-	-	21
918	Undetermined	-	-	<5
919	2.0	-	100	-

- Indicates no measurement taken.
*Calculated from 30 mR/hour at 1.5 feet.

April 1969

Table 8. - Measured Exposure Rates from Gaseous Discharge Tubes Used to Demonstrate Shadow or Fluorescence Effects in Secondary Schools

School Identification Number	Spark Gap Measurements (Centimeters)	Measured Exposure Rate mR/hour at:		
		6"	12"	24"
102	2.6	220	95	20
103	2.5	-	90	-
106	2.2	-	380	-
107	12.7	-	1,000	-
112	2.9	-	0	-
113	5.0	-	0	-
114	4.0	-	0	-
114	1.9	-	100	-
116	3.2	-	>5,000	-
204	Undetermined	10	2.5	0
207	2.5	40	10	2
208	1.5	5,000	1,000	70
209	7.5	0	0	0
209	7.5	500	100	25
212	1.5	10	5	0
213	1.3	100	50	50
216	7.5	180	70	30
219	3.5	1.5	0	0
303	2.5	300	150	50
306	Undetermined	0	0	0
308	3.2	370	150	40
309	3.2	180	90	30
311	2.2	190	60	32
312	1.9	180	70	20
316	Undetermined	0	0	0
317	2.5	0	1,800	320
407	7.0	-	<1	-
409	1.0	-	-	30
413	7.6	>5,000	1,500	150
414	3.2	-	-	0
415	3.8	-	-	<10
418	9.0	-	-	1,000
501	2.5	-	<1	-
504	2.5	-	-	9

Table 8. - (Continued)

School Identification Number	Spark Gap Measurements (Centimeters)	Measured Exposure Rate mR/hour at:		
		6"	12"	24"
508	2.0	-	-	5
509	Undetermined	-	0	0
511	5.1	-	-	27
512	Undetermined	-	-	5
513	Undetermined	-	-	200
517	5.4	-	-	600
518	Undetermined	-	-	150
520	Undetermined	-	-	1
602	1.2	2	0	0
603	0.5	1	0	0
605	3.5	0	-	-
607	3.3	500	50	20
612	3.2	-	1,125*	35
707	Undetermined	0	0	0
709	1.9	80	-	-
710	1.3	-	35	-
712	2.1	0	-	-
719	1.7	0	-	-
720	8.9	0	-	-
804	Undetermined	0	0	0
811	Undetermined	-	-	1
814	Undetermined	1	-	-
814	Undetermined	1.5	-	-
816	Undetermined	-	40	10
817	8.5	-	-	100
904	6.5	0	-	-
905	2.0	-	-	1.5
910	Undetermined	10	-	-
911	1.7	-	150	-
915	8.5	10	-	-

- Indicates no measurement taken.
*Calculated from 500 mR/hour at 1.5 feet.

April 1969

Table 9. - Measured Exposure Rates from Miscellaneous Gaseous Discharge Tubes in Secondary Schools

School Identification Number and Gaseous Discharge Tube	Spark Gap Measurements (Centimeters)	Measured Exposure Rate mR/hour at:		
		6"	12"	24"
Kinetic Energy Effect				
213	1.3	0	0	0
216	7.5	0.5	0	0
710	1.3	0	-	-
720	8.9	0	-	-
902	2.7	-	-	0
904	6.5	0	-	-
911	1.7	0	-	-
Canal Ray				
107	12.7	-	0	-
114	4.0	-	0	-
219	3.5	0	0	0
303	2.6	-	0	0
308	3.2	-	0	0
317	2.6	0	0	0
Vacuum Discharge Tube				
114	1.9	-	0	-
205	1.5	0	0	0
709	1.9	0	-	-
904	6.5	0	-	-
Cathode Ray Display				
816	Undetermined	0	0	0

Table 9. - (Continued)

School Identification Number and Gaseous Discharge Tube	Spark Gap Measurements (Centimeters)	Measured Exposure Rate mR/hour at:		
		6"	12"	24"
Geissler Tubes				
204	Undetermined	-	-	0
204	Undetermined	-	-	0
204	Undetermined	-	-	0
204	Undetermined	-	-	0
204	Undetermined	-	-	0
204	Undetermined	-	-	0
205	Undetermined	0	-	-

- Indicates no measurement taken.

Table 10. - Number and Type of High Voltage Generators in Secondary Schools
(181 Schools)

Region	Number of Schools	Number of Generators	Type					
			Van de Graaff	Tesla Coil	Static Generators	Induction Coil	High Voltage Transformers	Other
Total	181	875	168	137	110	365	79	16
I	20	96	18	16	2	56	4	0
II	20	87	25	17	8	35	2	0
III	19	65	15	15	7	23	5	0
IV	20	90	20	12	15	36	4	3
V	20	98	17	18	17	39	5	2
VI	20	83	6	8	17	40	9	3
VII	21	95	21	9	10	35	16	4
VIII	21	141	24	21	15	66	11	4
IX	20	120	22	21	19	35	23	0

April 1969

Table 11. - Number and Type of Radioisotopes in Secondary Schools (181 Schools)

Sources	Region									
	Total	I	II	III	IV	V	VI	VII	VIII	IX
No. of Schools	181	20	20	19	20	20	20	21	21	20
No. of all Isotopes*	909*	62	99	37	141	150	133	74	115	98
No. of known Isotopes	628	48	81	24	85	135	41	61	78	75
Sources										
^{3}H	4	0	0	0	1	0	0	0	0	3
^{14}C	65	5	6	1	6	11	6	6	14	10
^{22}Na	21	4	2	0	4	5	3	0	1	2
^{24}Na	1	0	0	0	0	0	0	0	0	1
^{32}P	60	3	8	2	3	11	4	14	2	13
^{35}S	13	0	0	1	2	5	1	1	3	0
^{36}Cl	1	1	0	0	0	0	0	0	0	0
^{45}Ca	5	0	1	1	1	1	0	0	1	0
^{51}Cr	1	0	0	1	0	0	0	0	0	0
^{54}Mn	2	1	0	0	1	0	0	0	0	0
^{59}Fe	8	0	0	0	2	0	2	0	4	0
^{60}Co	102	6	14	4	7	27	5	11	14	14
^{65}Zn	23	2	1	1	3	3	2	3	6	2
^{79}As	1	0	0	1	0	0	0	0	0	0
^{90}Sr	36	1	7	0	8	12	0	3	3	2
^{106}Ru	1	0	0	0	0	0	0	0	0	1
^{109}Cd	5	0	0	1	0	0	0	0	2	2
^{131}I	24	3	2	1	1	7	2	2	3	3
^{133}Ba	2	0	0	0	0	0	0	0	1	1
^{134}Cs	15	1	1	2	8	0	1	1	1	0

Table 11. - (Continued)

Sources	Region									
	Total	I	II	III	IV	V	VI	VII	VIII	IX
^{137}Cs	22	2	2	1	6	2	1	3	3	2
^{144}Ce	12	1	0	0	2	1	2	1	3	2
^{203}Hg	1	0	0	1	0	0	0	0	0	0
^{204}Tl	38	8	7	3	10	2	1	1	3	3
Long Lived Radium Daughters	129	10	27	0	14	37	11	14	9	7
^{226}Ra	26	0	3	1	6	6	0	1	3	6
^{235}U	2	0	0	2	0	0	0	0	0	0
^{238}U	2	0	0	0	0	0	0	0	1	1
^{241}Am	5	0	0	0	0	5	0	0	0	0
^{237}Np	1	0	0	0	0	0	0	0	1	0
No. of Unknown Isotopes	281	14	18	13	56	15	92	13	37	23
No. of Radioisotope Kits with Unspecified Contents	132	18	42	10	22	5	26	1	8	0
Miscellaneous Sources**	124	9	35	2	4	34	3	5	22	10

*Does not include Number of Radioisotope Kits with Unspecified Contents and Miscellaneous Sources.
**Includes radioactive compounds and ores.

April 1969

Table 12. - Number of Radioisotopes in Secondary Schools
(Excludes Kits with Unspecified Contents)

Radioisotopic Sources per School (Range)	Number of Schools	Number of Radioisotopic Sources
Total	181	909
0	50	0
1-4	64	147
5-9	36	243
10-14	17	207
15-19	8	136
20 and over	6	176

Table 12a. - Number of Radioisotope Kits in Secondary Schools
with Unspecified Contents

Kits per School (Range)	Number of Schools	Number of Kits
Total	181	132
0	149	0
1-4	24	34
5-9	3	15
10-14	2	24
15-19	2	33
20 and over	1	26

April 1969

Table 13. - Storage of Radioactive Materials in Secondary Schools
(181 Schools)

Region	Number of Schools	How Stored											
		Containers or Material Labeled with Radiation Symbol	No Radiation Label or Symbol										
			Desk		Cabinet		Storeroom		Lead		Metal		Plastic Containers
			Locked	Unlocked	Locked	Unlocked	Locked	Unlocked	Locked	Unlocked	Locked	Unlocked	
Total	181	86	3	2	17	21	12	30	4	6	6	8	9
I	20	7	1	0	3	3	1	0	1	2	0	0	0
II	20	17	0	0	1	2	4	4	1	1	3	1	2
III	19	8	0	0	0	1	1	4	0	0	0	0	0
IV	20	9	0	1	1	3	0	5	1	1	0	1	0
V	20	11	0	1	5	5	0	1	0	0	2	2	0
VI	20	8	0	0	0	2	0	6	0	0	0	1	5
VII	21	9	0	0	0	0	0	2	0	1	1	3	2
VIII	21	9	2	0	6	2	6	2	0	0	0	0	0
IX	20	8	0	0	1	3	0	6	1	1	0	0	0

April 1969

Table 14. - Number and Type of Non-Ionizing Radiation Sources in Secondary Schools
(181 Schools)

Region	Number of Schools	Number of Sources	Type						
			Micro-Wave Ovens	Radar	Magnetrons*	Klystrons*	Other RF Generators	Lasers	Ultra-Violet Lights
Total	181	368	1	4	32	42	63	15	211
I	20	36	0	2	0	7	10	2	15
II	20	37	0	0	0	1	2	2	32
III	19	46	0	0	2	0	16	0	28
IV	20	26	0	1	0	0	10	4	11
V	20	38	0	1	0	3	7	3	24
VI	20	14	0	0	0	0	3	0	11
VII	21	30	0	0	1	10	0	0	19
VIII	21	82	0	0	29	7	7	0	39
IX	20	59	1	0	0	14	8	4	32

*These devices are also potential emitters of ionizing radiation.

Table 15. - Use of Non-Ionizing Radiation Sources
in Secondary Schools
(181 Schools)

Source	Number of Sources	Method of Use			Not Used	Use Not Stated
		Demonstration by Instructor	Laboratory Use by Student	Used by Instructors & Students		
Total	368	140	34	77	57	60
Microwave Ovens	1	0	1	0	0	0
Radar	4	0	0	1	1	2
Magnetrons*	32	0	0	29	2	1
Klystrons*	42	4	14	2	9	13
Other RF Generators	63	21	7	7	20	8
Lasers	15	8	1	1	4	1
Ultraviolet Lights	211	107	11	37	21	35

*These devices are also potential emitters of ionizing radiation.

April 1969

Table 16. - Type of Ionizing Radiation Detection Instrumentation in Secondary Schools
(181 Schools)

Region	Number of Schools	Number of Instruments	Type							
			Scintillation	Geiger-Mueller	Ion Chamber	Alpha Counter	Pocket Dosimeters	Civil Defense Kits (a)	Other	Undetermined
Total	181	733	3	409	152	6	122 (b)	25	6	10 (b)
I	20	59	0	44	0	0	1	11	1	2
II	20	72	1	46	22	0	3	0	0	0
III	19	26	0	17	7	0	0	0	0	2
IV	20	127	0	64	46	4	12	0	1	0
V	20	113	0	72	21	1	11 (b)	1	1	6 (b)
VI	20	71	0	47	1	0	23 (b)	0	0	0
VII	21	155	0	49	44	1	61	0 (c)	0	0
VIII	21	63	1	42	8	0	11	0	1	0
IX	20	47	1	28	3	0	0	13	2	0

(a) The Civil Defense Kits reportedly contain a minimum of one GM survey, one Ion chamber survey instrument, and two dosimeters.

(b) Number of instruments not stated in one or more schools.

(c) Included under specific type of instrument.

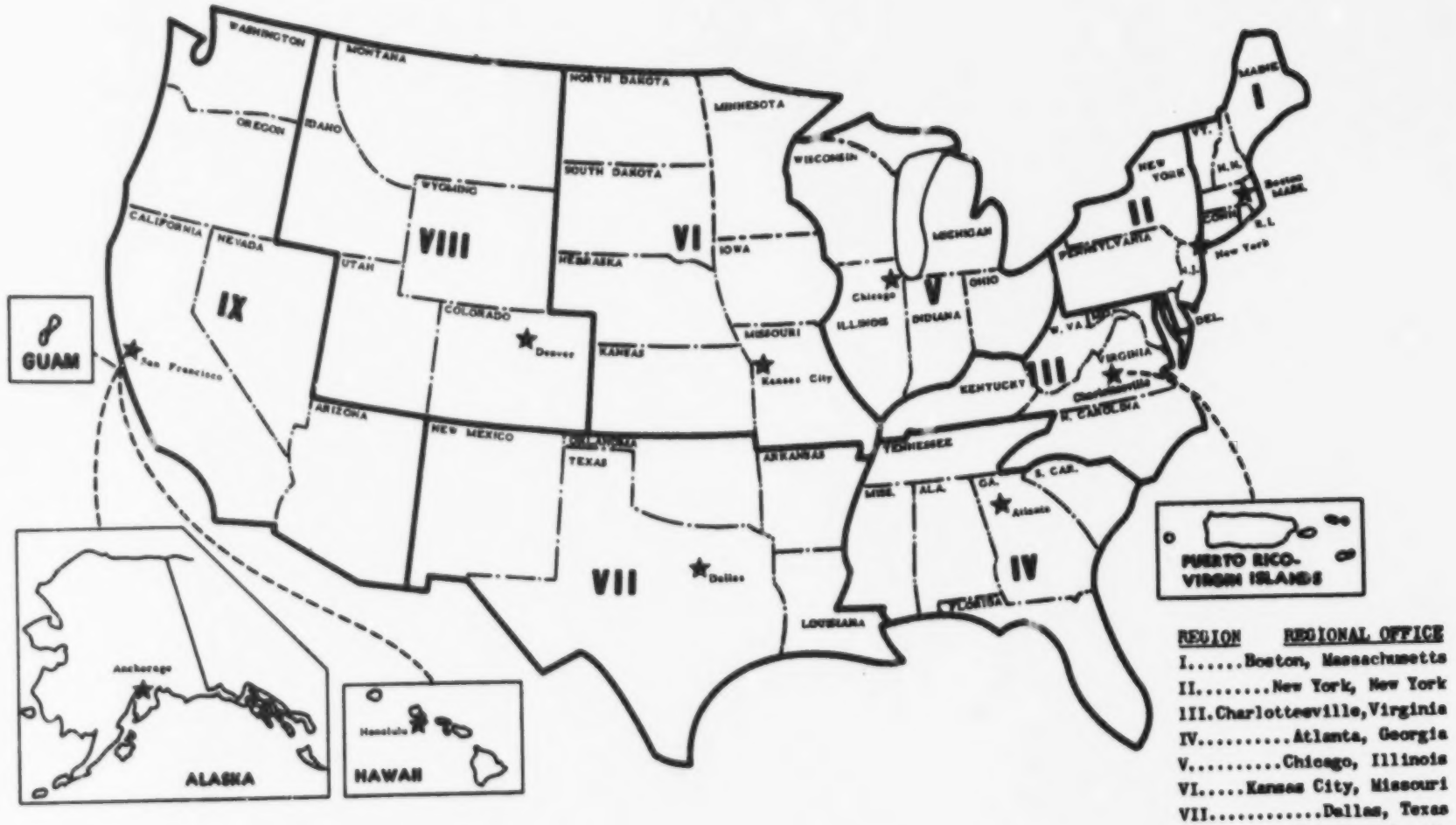
April 1969

Table 17. - Availability of NCRP Report No. 32
"Radiation Protection in Educational Institutions"
in Secondary Schools
(181 Schools)

Region	Number of Schools	Report Available in School			Report Not Available in School		
		Number	Read	Not Read	Number	Read	Not Read
Total	181	11	9	2	170	7	163
I	20	1	1	0	19	1	18
II	20	9	7	2	11	2	9
III	19	0	0	0	19	0	19
IV	20	0	0	0	20	0	20
V	20	0	0	0	20	0	20
VI	20	0	0	0	20	0	20
VII	21	0	0	0	21	4	17
VIII	21	0	0	0	21	0	21
IX	20	1	1	0	19	0	19

April 1969

Annex A



REGION — REGIONAL OFFICE

I.....Boston, Massachusetts
II.....New York, New York
III.Charlottesville,Virginia
IV.....Atlanta, Georgia
V.....Chicago, Illinois
VI.....Kansas City, Missouri
VII.....Dallas, Texas
VIII.....Denver, Colorado
IX.San Francisco, California

Geographic Locations of Department of Health, Education, and Welfare Regions

Annex B

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High School Radiation Survey Questionnaire

Identification No._____

HIGH SCHOOL RADIATION SURVEY QUESTIONNAIRE

Facility _____ Date_____

Address _____ School Principal _____

City _____ Person Interviewed _____

County/State _____ Title _____

OBJECTIVE OF STUDY

This study is designed to identify the quantity and types of potential and actual source of radiation in a selected number of high schools. The high schools have been selected in nine areas across the continental United States.

The recently enacted Public Law 90-602, "Radiation Control for Health and Safety Act of 1968," requires that the Secretary of Health, Education, and Welfare determine the status of electronic products in the United States that are designed to produce radiation or, in their operation produce radiation as a by-product of their use. Radiation is defined as any ionizing and non-ionizing electromagnetic or particulate radiation. We would like to ask you a few questions on the use of electronic products and other radiation emitting sources in your high school. We would also like to look at these products and monitor some of them as they would be used during a demonstration by the instructor or by students in the laboratory.

I.D. No. _____

HIGH SCHOOL RADIATION SURVEY QUESTIONNAIRE

A. How many students are enrolled in this school? _____

How many students are enrolled in Science courses? _____

B. Do you have any equipment in your high school that is used with or for the production of X-rays?

SOURCE (Include operating characteristics if known) (1)	Number (2)	USE (times per academic year)		
		Not Used (3)	Frequency of Demonstration (Used by Instructor) (4)	Frequency of Laboratory (Used by Student) (5)
A. X-ray tubes: (1) Cold cathode				
(2) Coolidge				
(3) Other (Specify)				
B. X-ray Equipment (1) Fluoroscope (hand held)				
(2) Fluoroscopic (other) Specify				
(3) Radiographic				
(4) Diffraction				
(5) Other (Specify)				

Expires June 30, 1969
Bureau of Budget approval
number 85-S 69006

I.D. No. _____

C. What types of high voltage generators, static or induction, do you have for use in your high school?

SOURCE (Include operating characteristics if known) (1)	Number (2)	USE (times per academic year)		
		Not Used (3)	Frequency of Demonstration (Used by Instructor) (4)	Frequency of Laboratory (Used by Student) (5)
(1) Van de Graaff				
(2) Tesla Coils				
(3) Static Generators				
(4) Induction Coils				
(5) High voltage (> 10 kV) transformers				
(6) Other (Specify)				

I.D. No. _____

D. Do you have equipment such as gaseous discharge tubes or high voltage vacuum tubes, which are connected to high voltage generators (greater than 10 kV)? These tubes can produce X-ray incidental to the use for which they are employed.

SOURCE (Include operating characteristics if known) (1)	Number (2)	USE (times per academic year)		
		Not Used (3)	Frequency of Demonstration (Used by Instructor) (4)	Frequency of Laboratory (Used by Student) (5)
A. Cathode ray tubes: (1) Heating effects				
(2) Deflection effects				
(3) K.E. effects				
(4) Shadow effects				
(5) Fluorescent effects				
(6) Canal Ray				
(7) Vacuum effects				
(8) TV picture tube				
(9) Cathode ray display				
(10) Other (Specify)				
B. Particle Accelerators: (1) Van de Graaff (with beam tube)				
(2) Other (Specify)				
C. High Voltage Tubes: (1) Rectifiers				
(2) Magnetrons				
(3) Regulators				
(4) Other, (e.g., klystrom, vacuum switches)				

I.D. No. _____

E. Do you have radioactive materials? Specify below

Isotope (Type of Device) (1)	Radiation Sign or Label on Isotope or Device (2)	Activity in microcuries, etc. (3)	Date of Specified Activity (4)	How Used in Classroom (5)	Frequency of Use (6)	Registered or Licensed with State Radiation Control Agency (7)

Describe how isotopes are stored. _____

_____

_____

I.D. No. _____

F. Are radiation detection instruments available for use in this school? This would include Civil Defense instruments stored here, if they are available for use by you or the student.

Indicate make and model of each instrument:

Type	Make	Model	Operative Yes	Operative No
_____	_____	_____	☐	☐
_____	_____	_____	☐	☐
_____	_____	_____	☐	☐
_____	_____	_____	☐	☐

G. All the questions preceding this one dealt with ionizing radiation. We would like to ask a few questions about non-ionizing radiation sources.

1. Do you have any microwave devices, such as ovens, radar, or masers?
2. Do you have any lasers?
3. Do you have any ultraviolet light sources?

SOURCE (Include operating characteristics if known) (1)	Number (2)	USE (times per academic year) Not Used (3)	Frequency of Demonstration (Used by Instructor) (4)	Frequency of Laboratory (Used by Student) (5)
1. Microwave devices: a. Ovens				
b. Radar				
c. Masers				
d. Magnetrons				
e. Klystron				
f. Other R.F. generators				
2. Laser Systems				
3. Ultraviolet light sources (Specify)				

I.D. No. _____

H. Do you have any other types of potential or actual sources of radiation?

Specify

I. (1) Have you read the National Council on Radiation Protection and Measurement Report No. 32, "Radiation Protection in Educational Institutions"?

Yes ☐ No ☐

(2) Do you have available in your school a copy of the NCRP No. 32?

Yes ☐ No ☐

Reviewed by:

_____
State

_____
(Date)

Survey Team

_____
State

_____
PHS

_____
(Date)

Annex C

X-ray Exposure Control Laboratory
Division of Medical Radiation Exposure

Recommended Radiation Survey Procedures for High School Devices

Following is some general information which may serve as a helpful reminder while in the field with respect to the recommended survey procedure. It is not intended to answer all anticipated questions or to be a substitute for instruction at the X-ray Exposure Control Laboratory.

Survey Manual:

You will note in the manual provided each survey group that opposite the picture of some tubes is a line drawing which relates to the survey procedure for that tube. Drawn from these tubes are one or more lines (radials) indicating the direction from that tube at which radiation readings should be made. These positions are based on laboratory results which show the direction of highest X-ray intensity. The purpose of this approach is to standardize the results obtained by all survey teams. For this reason, please follow the survey procedures recommended for each tube.

Radiation measurements around the small Van de Graaff accelerators and X-ray tubes should receive priority. These devices obviously present the greatest radiation hazard. In addition, our laboratory investigations have confirmed that magnetic, fluorescence, and heating effects tubes are also possible sources of X-rays, therefore, radiation measurements are desirable on these tubes as well. Laboratory investigation of the X-ray output of the other tubes pictured in the manual did not prove them to be X-ray sources, but it is known that under certain conditions they may be. You will have to use your judgement regarding measurements on these tubes depending upon time and availability.

CS-40A Survey Meter

The CS-40A is calibrated with a correction factor of approximately 1.00 obtained at 20 kVp and 0.30 mm Al. equivalent filtration (11.8 keV eff. energy). Since there may be some chamber directional dependence between end and sides, readings should be made with the side of the chamber toward the radiation source. This is the manner in which the instrument was calibrated. Also when Tesla coils, induction coils, and other similar devices are used as voltage sources, all readings should be taken with the CS-40 completely enclosed in the RF shield.

Radiation Safety

Consideration must be given to levels of X-ray exposures to yourself and others in the immediate vicinity of devices designed specifically to produce X-rays. The output of the Van de Graaff accelerator and unshielded X-ray tubes may be on the order of tens to hundreds of R/hr within a few feet of the tube. For this reason, shielding should be provided or other precautions taken. Distance is at least a partial solution since the CS-40A may be stood on end for taking readings while standing away from the device. It is appreciated that in some instances the operator may not be able to stand back because of the

design of the device or experimental setup. Therefore it is recommended that a leaded apron be carried and worn when making radiation measurements around the devices having relatively high output. In setting up the device one might also give thought to the possibility of taking advantage of the shielding afforded by walls, laboratory benches, etc. In any event each situation will require special consideration in deciding what the best approach may be.

Survey Procedure

1. Position the tube in the same horizontal plane as the center of the chamber. Refer to the appropriate line drawing in the manual to determine the positions where readings are desired. In all cases make the initial reading at 2' from the device. (All measurements are made from the anode or target of the tube to the center of the CS-40A chamber.)

2. Record the reading obtained at two feet. Move to the next radial and take a reading at the same distance. After taking readings in this manner on each of the recommended radials, the radiation measurements on that device are completed.

3. If there is no radiation detectable at the starting distance, record it as zero and move the meter closer until a reading is obtained, preferably on the X(10) scale or higher. Whenever possible, the second reading should be taken at 6" increments from the anode. After a distance is determined at which a reading is possible, proceed as in #2 above making readings on each radial.

4. If the original reading is beyond the range of the CS-40A, move it back in intervals of 6" until an on-scale reading is obtained.

The designation of specific distances and radials does not preclude making measurements at any other distance or location. If circumstances warrant or because of special interest, measurements are made at other positions, the results should be recorded on the survey form.

Please do not hesitate to provide information which will help one unfamiliar with the situation to evaluate the readings recorded. Any measurements which you believe require qualification should be explained in the space provided on the survey form. The back of the survey form should be used for sketches and any other additional information thought necessary.

Spark Gap (Voltage) Measurements:

For the purpose of obtaining an estimate of the potential at which the various tubes are operated, it is important to obtain a spark gap measurement when applicable. Of course, if a meter voltage reading is available, this is preferred. The spark gap measurement should be obtained by closing the spark gap until arcing occurs. The electrodes may be slowly closed by

pushing them with something which provides insulation (e.g. a book, piece of wood, etc). DO NOT touch them with the hands, even though it appears the ends are insulated. When arcing just begins to occur, shut the generator off and measure the spark gap distance in centimeters. Record this distance and other pertinent information as requested on the survey form. If the voltage source is hand held (e.g. Tesla coil) let the voltage source discharge to ground and make the measurement after determining at what point arcing occurs.

Sidney D. Heidersdorf
William S. Properzio
Ray C. Woodcock

April 16, 1969

HIGH SCHOOL RADIATION SURVEY DATA SHEET

DATE:_____ SURVEY TEAM:

SCHOOL #:_____

TUBE OR DEVICE NAME:_____

HIGH VOLTAGE GENERATOR:

TYPE:_____

VOLTAGE OR SPARK GAP:_____

DESCRIPTION OF SHIELDING AROUND DEVICE:

RADIATION MEASUREMENTS:

INSTRUMENTS USED:

- ☐ CS-40A WITH RF SHIELD
- ☐ CS-40A WITHOUT RF SHIELD
- ☐ OTHER (SPECIFY)_____

INSTRUMENT READINGS:

RADIAL	DISTANCE	READING

COMMENTS: (DESCRIPTION OF PROTECTIVE DEVICES, WARNING SIGNS, UNUSUAL OBSERVATIONS, ETC.)

Spark Gap Voltage Conversion Table*

Peak Voltage (Kilovolts)	Spark Gap Needle Points (Centimeters)
5	0.42
10	0.85
15	1.30
20	1.75
25	2.20
30	2.69
35	3.20
40	3.81
50	5.20
60	6.81
70	8.81

*Spark gap voltage for air at 1 atmosphere, 25° C. Taken from Handbook of Chemistry and Physics, 41st Edition. Also reported in National Council on Radiation Protection and Measurements "Radiation Protection in Educational Institutions," Report No. 32, July 1, 1966, page 14.

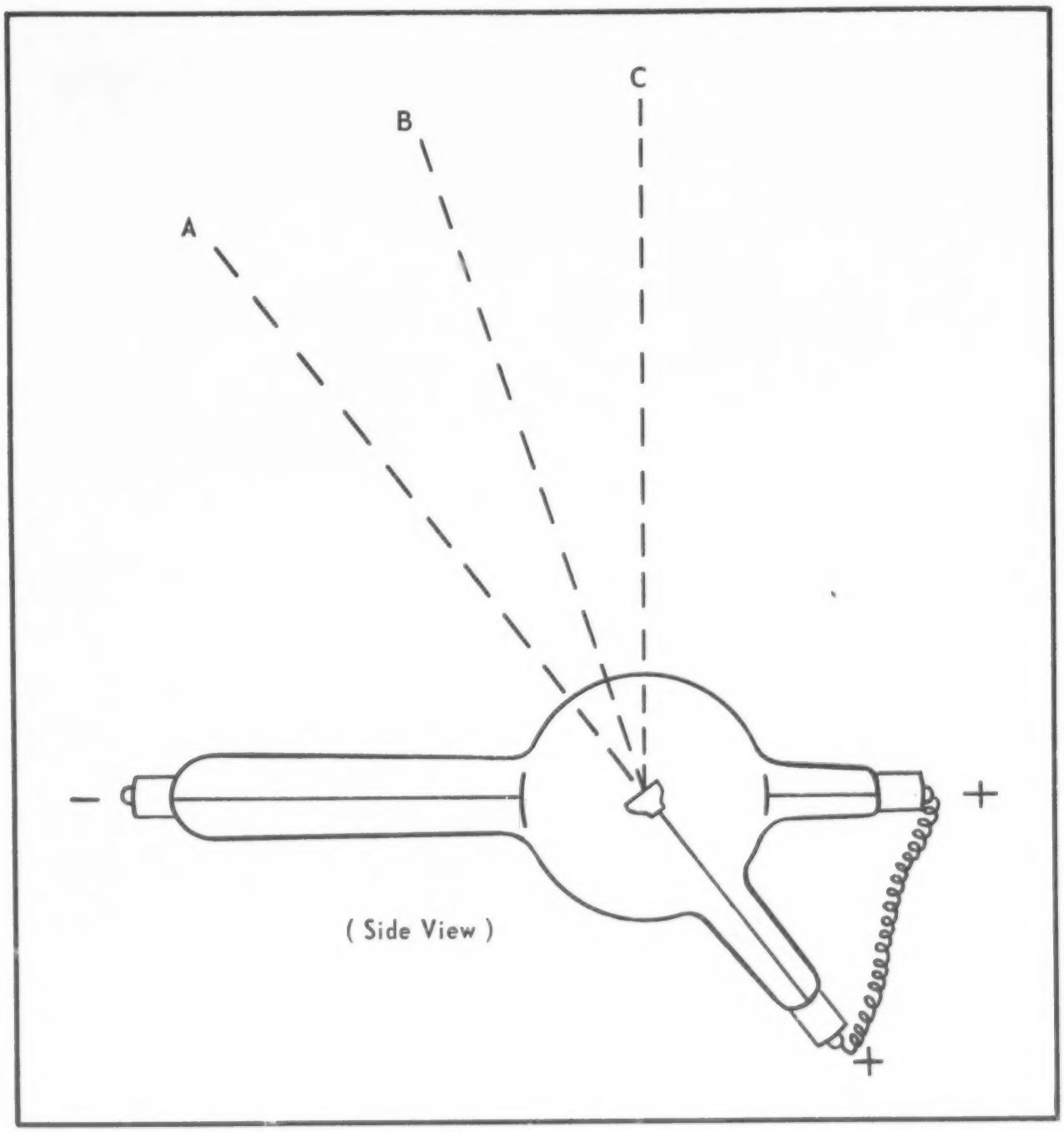
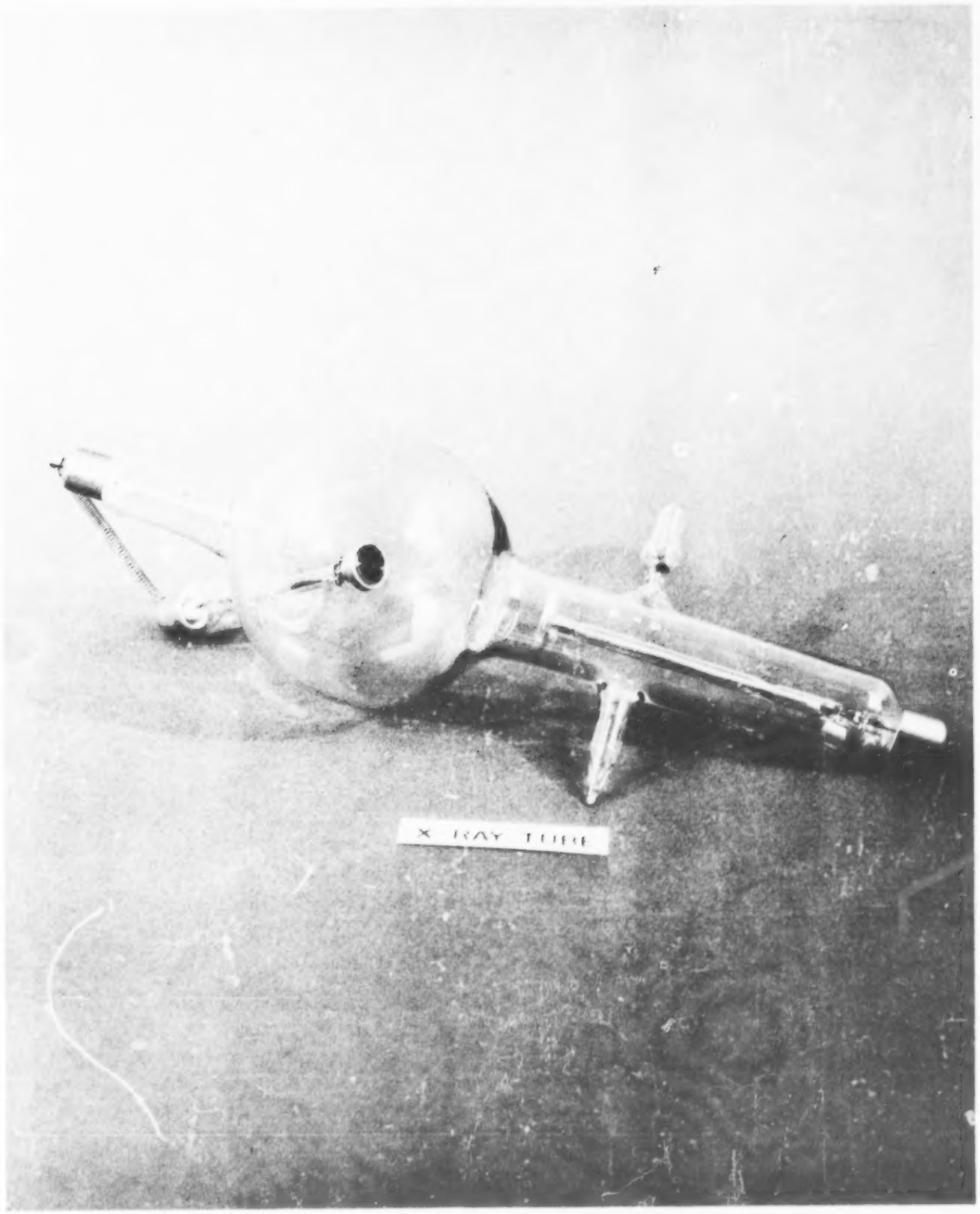


Figure 1. Cold Cathode X-Ray Tube


X RAY TUBE

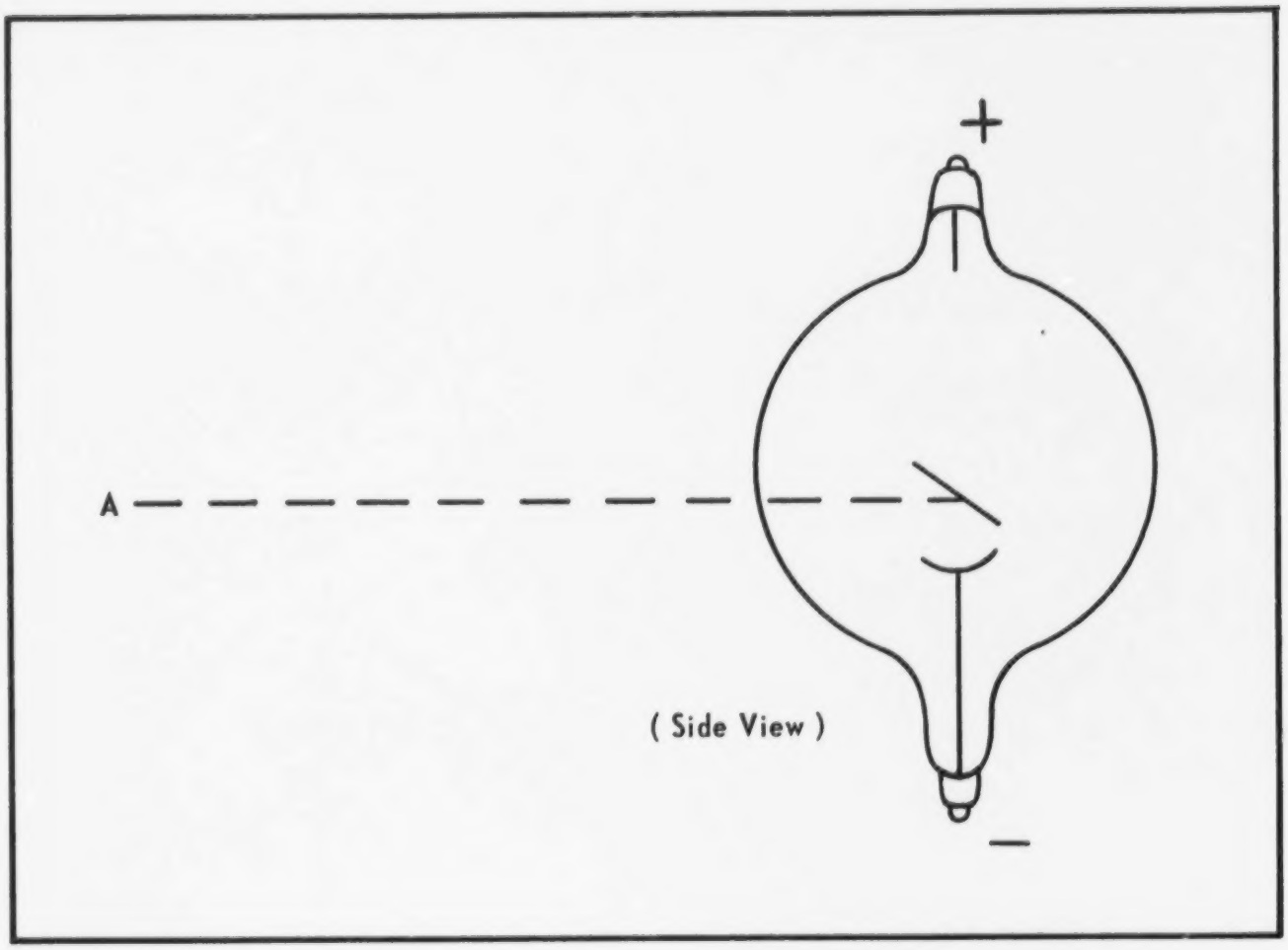
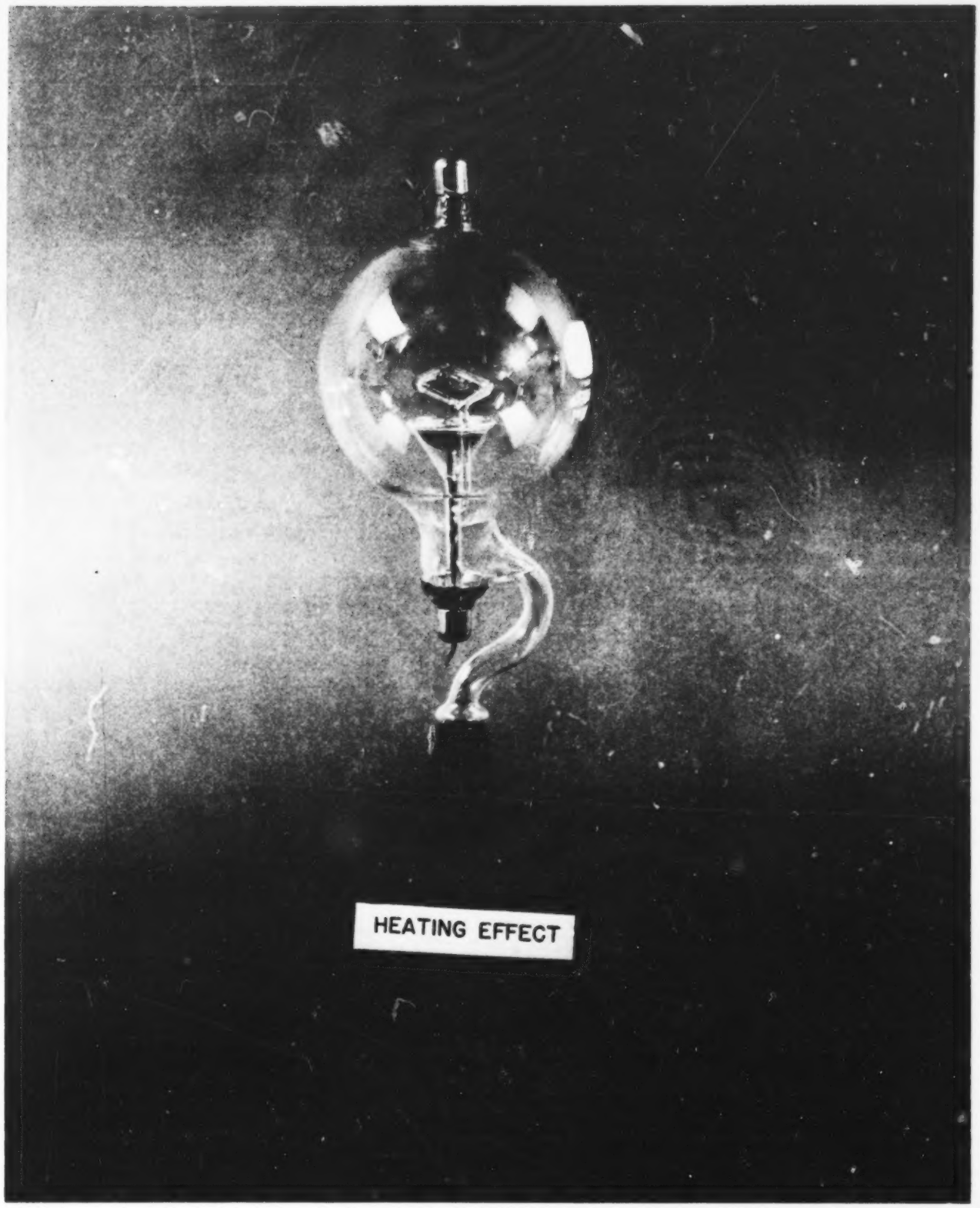


Figure 2. Heat Effects Tube


HEATING EFFECT

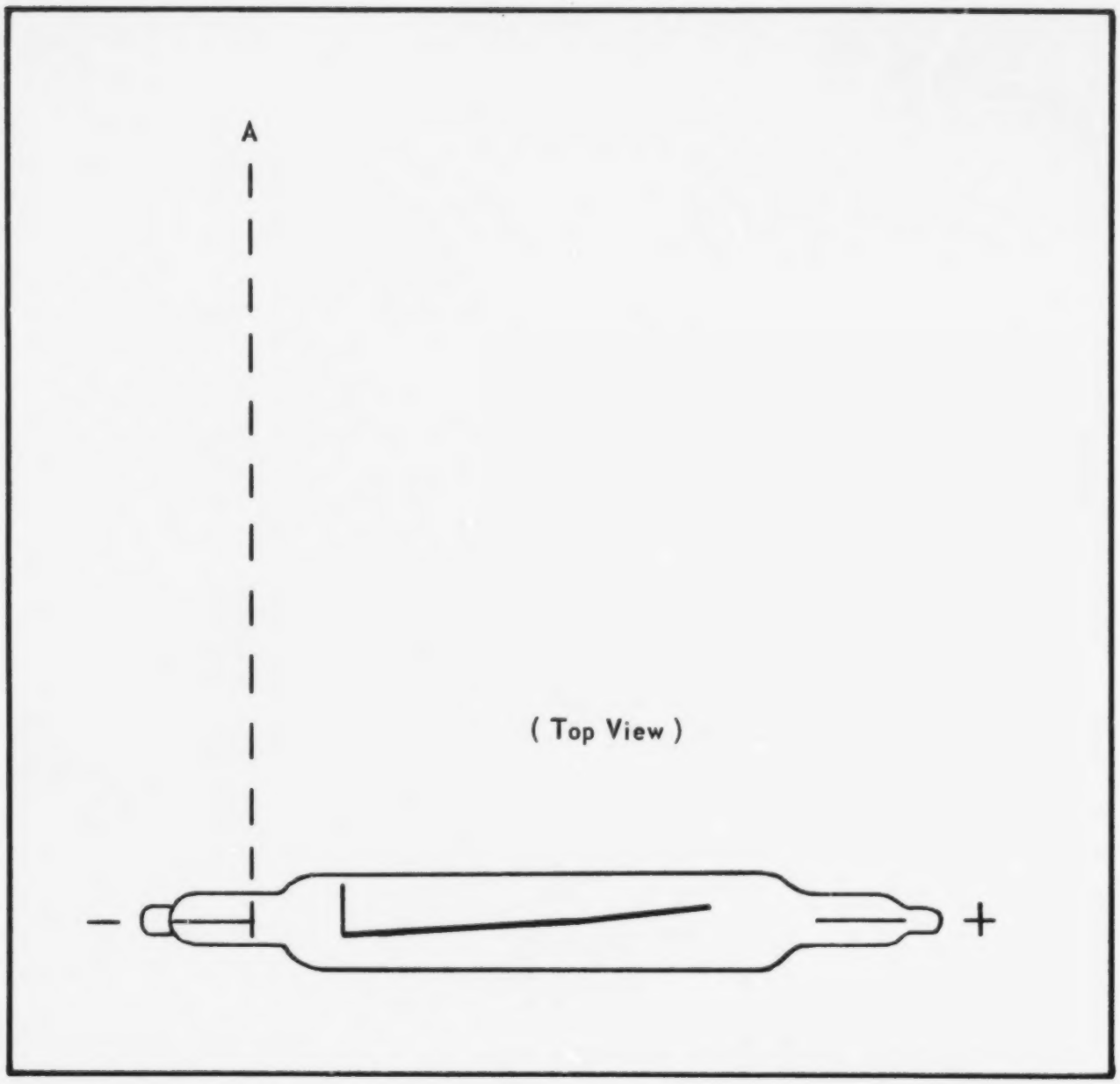


Figure 3. Deflection Effects Tube

MAGNETIC EFFECT

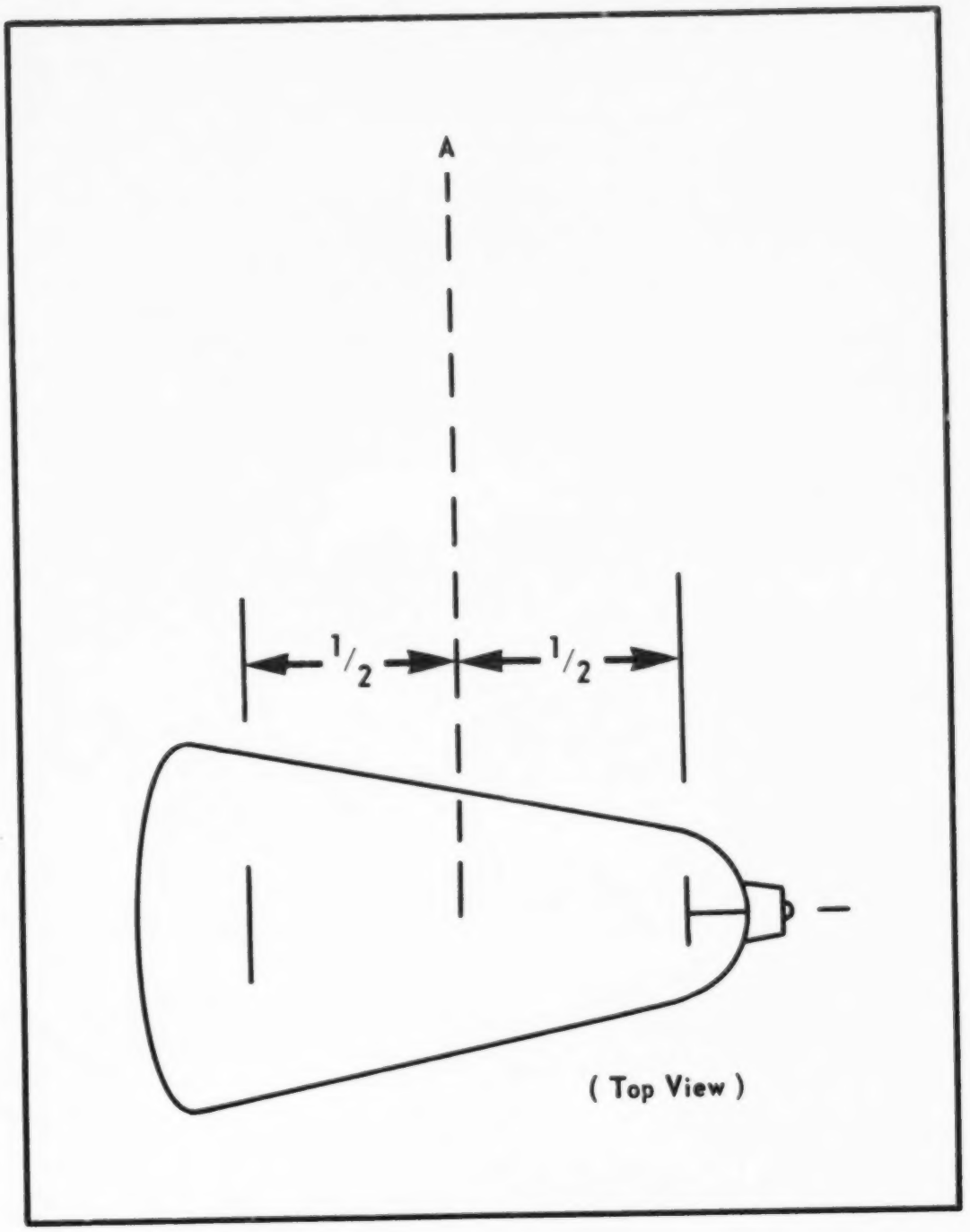
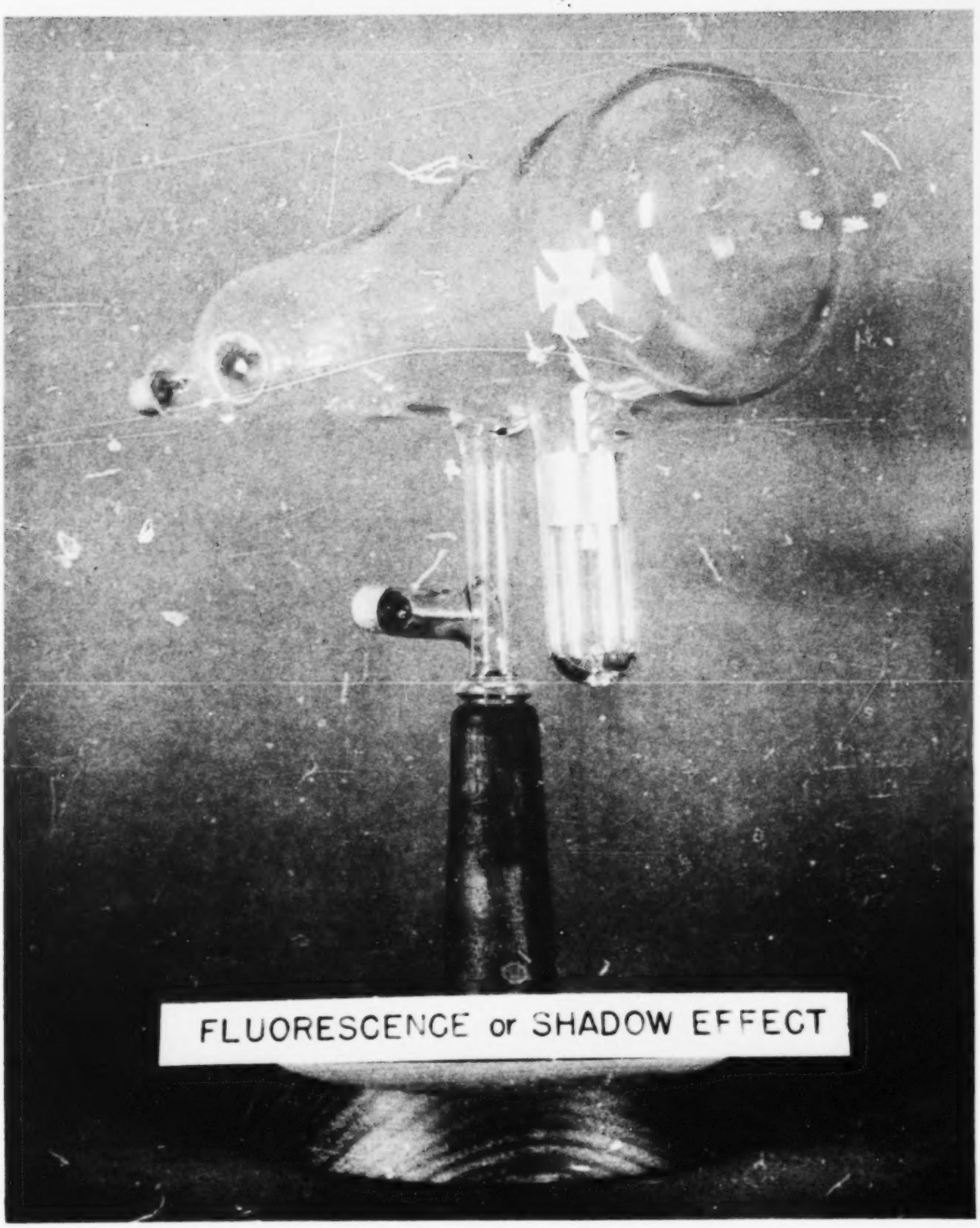


Figure 4. Fluorescence Effect Tube


FLUORESCENCE or SHADOW EFFECT